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SOME THOUGHTS ON YIELD*

Few economic questions are simple and, most certainly, the economics of crop production is not one of those few. It would not be unfair to say the standard measure of success in improved cultural methods, in the production of new varieties and so on is yield. That, however, is a preliminary step only; experiments can show only the potentialities of any proposed change in the standard agricultural practice. There remains the question of whether that change can be made without incurring additional charges which will more than offset the value of the increased yield. The work of the agrobiologists illustrates the point very clearly. They have shown that there is in each plant an inherent capacity to yield; that is, a capacity which will not be exceeded in the perfect environment when each and every environmental factor affecting plant growth is optimum. But they also show that each successive increment in any particular factor, say amount of nitrogen, produces a smaller effect when measured as yield. The time soon comes, therefore, when the cost of the added dose exceeds the value of the increase obtained as the result of the application.

Another pertinent point arises from a consideration of the theory of limiting factors. Plant growth, and with it yield, is limited by that factor which is in least supply. However many of the factors are present in optimum amount, if only one is deficient, growth and yield will be determined by that factor. It is useless, for instance, to evolve and introduce into general cultivation a new variety of a crop of which the inherent capacity to yield is greater than that of the standard crop, without considering the conditions of growth. Unless these are simultaneously improved, no increase will be obtained and the greater inherent capacity will remain potential. A good example of this is to be seen in India. The statistical returns for wheat in northern India show that the average yield is still the same as at the beginning of the century—as a matter of fact the average for the last quinquennium for which returns are available is slightly less (by an amount, however, which is not statistically significant) than the average for the first quinquennium of the century. This is the result of forty years of evolution of new varieties by the plant breeder. A succession of new varieties has been introduced

* Article by H.M.L. reproduced from *International Sugar Journal*, Vol. XLVI, No. 551, 1944.

into cultivation and these undoubtedly have a capacity to produce yields much higher than the standard wheats earlier grown, but that capacity has remained potential and will only be realized when the conditions under which they are grown are improved. The limiting factor lies in the soil. But the soil itself is a complex of different factors, physical, chemical and biological, improvement of any one of which may influence yield little or not at all, for the limiting factor may lie in one of the other factors involved. Progress will result only from a balanced and synchronized study of agriculture in all its aspects ; it will result from team work, and concentration on one aspect is likely to result in much wasted effort. The division of the sciences into the different and almost water-tight compartments of the various "-ologies" is not the most promising basis for the improvement of so complex a subject as agriculture.

Such are the thoughts that arise from consideration of the subject of yield in its technical aspect, but they are merely of a preliminary nature. Given, as the result of technical investigation in all the above directions, evidence to suggest that certain modifications in agricultural practice, in the widest sense of that phrase, are desirable, the question arises as to how these modifications may best be introduced into general farming practice. The nature of this problem may best be illustrated by a particular instance for which, for concordance's sake, the same example as above, drawn from India, may be taken. There is here no question of an unbalanced technical study of wheat in northern India with emphasis on breeding : as much attention has been given to the soil and conditions of growth of the wheat plant as to breeding. Yet no appreciable increment of the general yield has resulted. The cause lies, not in the technical work but in failure to apply its teaching to practice. When the reason for this failure is sought, it is found to lie in the economic organization of the industry. That organization is on a peasant basis with small holdings varying from 2.5 to 5 acres, with high indebtedness and an absence of fuel which compels the peasant to use most of his cattle droppings as a substitute. The peasant, or *ryot*, has not the facilities for intensive cultivation, nor the means to purchase either fertilizers or the fuel which would liberate organic matter by which the humus content of the soil could be raised. The question of yield, thus, is directly linked with the question of the terms under which the land is held. It is primarily a question of land tenure, yet—if memory serves aright—land tenure being a revenue subject was specifically excluded from the terms of reference of the Royal Commission of Agriculture which made its investigations shortly after the last war. Of the technical services working under such conditions it might almost be said that, through no fault of their own, *parturiunt montes et nascitur ridiculus mus*. What is lacking, in fact, is not knowledge but the means to turn knowledge to practice ; what is wanted in the immediate conditions is, not more knowledge but the application of existing knowledge. If the division of the "-ologies" each working in a separate water-tight compartment is one source of weakness, the sum of the "-ologies", technology as a unit, may be equally ineffective as a water-tight department divorced from the economic conditions attaching to the practice of agriculture. The present writer was, as head of an Agricultural Department and Member of the Legislative Council of a Province of northern India, compelled to defend his Department against criticism on the grounds that the demonstration farms did not pay. The defence was easy ; his own farm as a subordinate member of the service had always paid. But that was a mis-directed criticism ; they were made to pay because of the financial freedom conferred by their ownership, a freedom which allowed methods to be adopted which were entirely beyond the capacity of the small peasant. It did not follow that the peasant, lacking that financial freedom, could adopt the same methods. The influence of this freedom is, perhaps, best seen where the two systems, peasant and plantation, are closely intermingled. Such is the case in the cane industry of the West Indies, particularly Trinidad with its cane farming. Here it is estimated that the difference between plantation and peasant yield is 6 tons per acre on plant cane (1933 figures, 30 tons and 24 tons respectively) and 4 tons per acre on ratoons (20 tons and 16 tons respectively). The conclusion to be drawn from such facts is that there is available the technical knowledge largely to increase the yield of crops ; the difficulty lies in the application of that knowledge. The almost inevitable conclusion is that agriculture, in as far as yield is concerned, must be organized in units sufficiently large and of sufficient financial strength to render the application of technical knowledge feasible in practice. As that may appear to be an argument in favour of the plantation system, it may be as well to issue a caution. It is not necessarily so ; there are examples both of cooperative association of peasant units providing the necessary financial basis and of large-scale units (plantations) with the area distributed among a host of peasant tenures. Denmark offers an example of the former, and Fiji and the Sudan of the latter, and the degree of success depends apparently on the extent to which the spirit of co-partnership is incorporated into the scheme.

That point, the nature of the financial organization, cannot be discussed here ; it has already been briefly considered earlier (1). A full study of the various systems adopted would show the importance of the rôle of finance in determining organization for agricultural production. There remains, however, a further point ; the nature of the technical advice which the provision of financial facilities would render available. The basis of technical advice is research and research is commonly divided into two ; pure and applied. The difference between the two is readily defined ; the former is elusive in its aims and the worker moves towards an unknown goal, in the latter, the

(1) I.S.J., 1933, p. 103.

goal is a solution to a specified practical problem. But, if definition is easy, practical distinction between the two is difficult for they merge into each other. Rarely is it possible for any organization working on commercial lines with its financial limitations to finance pure research ; that is the work of a University. The practical problem is to draw the line between that research which is properly the function of a University and that which so directly affects practice that the commercial organization may be justified in incurring the expense of carrying a technical staff as an overhead. There is sufficient evidence in the methods by which the answer to this problem has been sought in different countries, to provide a broad conclusion.

In industry, only the largest units have found profit in entering the field of pure research ; the financial risks are too great. The tendency has been, therefore, to leave such work to the Universities or to Government frequently working through hybrid bodies, Research Associations, controlled by Committees composed of representatives partly of the industry and partly of Government. Experience in England since the last war, when the latter method received a great impetus, has failed to provide a solution of the problem, as is evidenced by the present cry for a closer association between research and industry. It would seem that the research worker is a wayward individual, always drifting along the path of inclination and unwilling to be bound by a limited practical objective. The failure of these methods appears to lie in the non-recognition of this waywardness. The worker in pure research is an essential element in industrial progress ; it is in the course of his meanderings that are brought to light those deeper secrets of nature which may be turned to practical account. But his is not the temperament to follow these bypaths to their practical conclusion. For this different temperament is required and a different training ; a training in technique and a technical knowledge which will enable him to grasp the openings presented by the newer knowledge. But it is a temperament which requires a restraint which will counteract the desire, inherent in all, to follow their inclination, and all the evidence points to the conclusion that this restraint is best applied by making these "interpreters of research" responsible to the industry alone. This thought envisages industry as organized into units sufficiently large to carry a technical staff responsible to, and paid by the industry itself. The distinction, too little recognized, lies between the research worker, following his bent and having an assured income such as is provided by a University, and the "interpreter" paid by his capacity to "deliver the goods."

The world's sugar industry is carried on under very divergent conditions in the different areas in which sugar cane is grown and, for many decades, the agricultural aspect of cane cultivation has been the object of scientific study of growing intensity. A practical, if not perfect (for it leaves out cost) measure of the success of science in improving cane cultivation is yield and a comparison of the increases of yield per unit of area obtained under the different conditions should offer evidence of the efficiency of the different ways in which attempts have been made by the respective industries to take advantage of scientific knowledge. Unfortunately the records of yield for many of the countries involved are not available or lack concordance, but there are sufficient to justify a tentative conclusion. The collected data are too extensive to be given here but attention is at once attracted to three countries, Java, Hawaii and Fiji ; all three are countries in which the industry maintains at its own expense a technical staff to supervise cultivation.

The facts of the Java industry have recently been reviewed (2) ; there has been a ten-fold increase of yield since the start of the industry as an independent organization in 1870. The increase has been especially marked in recent years, yield in quintals sugar per hectare rising from below 1,000 about 1920 to some 1,400 when war broke out. That review gives an idea of the work carried out by the extensive staff of "interpreters" employed and paid for by the industry. Hawaii entered the field much later but has built up a technical service, responsible to the industry. Like Java, it maintains a central experiment station which works in close collaboration with estate staffs. Unlike Java, the estates have permanent possession of the land they cultivate. The yield per hectare, 1909-10 to 1913-14, averaged 930 quintals ; in only one year before 1923/24 did it exceed 1,000 quintals and, from that date it has consistently risen to reach some 1,600 quintals.

The conditions in Fiji are very different. The average yield per hectare (1909-10 to 1913-14) was 311 quintals but dropped heavily between 1918 and 1921. The reason is not in doubt ; it was the labour troubles following the cutting off of the indentured labour supply from India. Up to that time, the industry was run on typical plantation lines and had gradually passed under the monopolistic control of the Colonial Sugar Refining Company. Drastic steps had to be taken and, fortunately, the Company was controlled by courageous men. By stages the estates were cut up into peasant holdings which were leased to the freed indentured labour which was unwilling to work for a wage. A technical staff was employed to supervise and help the tenantry. In addition to supervising the cultivation, the staff organizes cooperative harvesting by groups of tenants and supervises the loans given for purchasing implements and cattle and for the erection of housing. The tenant grows a portion of his holding in cane and is free to grow other crops on the remainder for his own use. The scheme, orginally tentative, has proved so successful that only a small area for experimental purposes is now under direct cultivation by the Company. That was the position on the outbreak of war. From the time of the reorganization yields have gradually risen. Returning to the earlier average of 311 quintals per hectare, they now approach, and have on

(2) I.S.J., 1944, p. 61.

occasion surpassed 600 quintals. It is also on record that the yields obtained by the peasants are not less than those obtained on land under direct cultivation; a fact which is in strong contrast with the earlier fact, quoted above, for the West Indies.

It would take too long to pursue the analysis through all the sugar-growing countries; two only can be mentioned. In contrast with the above, yield in northern India has risen from an average of 2600 lb. gur per acre in 1907-08 to 1911-12 to only 3500 lb. in spite of the substitution of Coimbatore canes. India's increased production results mainly from increased acreage. In British Guiana the yield of sugar per acre has risen from some 1.8 tons per acre around 1902 to over 3 tons. This apparent exception is probably due to the dominance of the sugar industry in the Colony's economy.

There is, in the above examples drawn from the sugar industry, presumptive evidence that practical achievement is best attained when a technical staff is employed by the industry itself. A wealth of evidence could be gathered from without, pointing in the same direction, and one example may be given. Denmark is a country in which the technical services are employed by the industry, in England these services are official. In the former, the quinquennial averages for barley have steadily risen from 13.77 cwt. per acre in 1893 to '97 to 23.5 cwt. in 1933 to '37; in the latter, starting from 14.3 cwt., they remained fairly constant—actually dropping slightly—till 1918 to '22 and only rose to 16.7 cwt. in 1933 to '37. In Ireland, where the brewing interests take an active interest in the technical development of the crop, there has been a fairly steady rise from 16.7 cwt. to 20.3 cwt. over the same period.

Realization of high yields, thus, is dependent on many factors, some of which are economic; and not the least of these latter are the employment of the technical staff by, and its responsibility to the industry. That implies an industry organized in large units and this is generally opposed on social grounds, for it is commonly visualized as a plantation run on paid labour. Fiji provides the answer to that objection; full development of agricultural wealth and social progress are compatible. The key lies in the organization which recognized the pyschological distinction between research workers and "interpreters of research." Provision for research proper is best made by Universities and the necessary liaison effected by provision of facilities for research workers by which they will at intervals be able to conduct this more fundamental work at the local stations.

H.M.L.

FIELD EXPERIMENTS IN CACAO RESEARCH, 1943-44

BY

E. E. CHEESMAN

IT is usual for separate reports to be published on the work of the Cacao Research Scheme of the Imperial College of Tropical Agriculture, but for the year 1944 this procedure appears unnecessary. The work of the Botanical Section has been practically confined to the upkeep and recording of the twelve acres of field experiments at River Estate. The results are essential to the programme as a whole, and of some interest in themselves, but do not call for much discussion. This summary is accordingly presented as an interim report for the information of those interested. For particulars about the numbering of the experiments, their objects, composition and establishment, reference may be made to the Tenth Annual Report on Cacao Research (1940) pp. 3-11. Results for the crop year 1942-43 were given in the Eleventh Report on Cacao Research published in 1944.

Four experiments, each comprising 576 pickets, were recorded for the crop year 1943-44, which ran from 1st September, 1943 to 31st August, 1944. Actually there were no pickings in September, and three of the experiments finished crop in July, but from October to July harvesting was monthly.

The season was on the whole favourable and yields were satisfactory. CRB 1 and CRB 3 both showed more than 50 per cent increase on their yields of 1942-43. CRB 4, recorded for the first time, yielded at a rate of 164 lb. dry cacao per acre, or ½ lb. per tree at three years old. Three good clones in CRB 1, six years old, averaged 740 lb. per acre.

CRB 2 alone showed a sharp reduction in yield, which is difficult to explain as the trees appear healthy. It had carried a very heavy crop (367 lb. dry cacao per acre) in 1942-43, when only four years old, and this may have had an effect on the following year's performance, but no conclusions can be drawn at present. As CRB 3 this year has likewise carried 369 lb. per acre at four years old, it will be interesting to see whether the latter will fall off similarly in 1944-45.

Yields (calculated as lb. dry cacao per acre from the recorded weights of wet cacao in grammes) and pod values (pods to 1 lb. dry cacao) are recorded for all the clones in Table I, and the yields of previous years are included for comparison. In perusal of Table I, it should be remembered that both 1940-41 and 1941-42 were unfavourable seasons, a fact which largely accounts for CRB 1 and CRB 2 starting crop at much lower levels than CRB 3 and CRB 4. Comments are offered on each set in turn.

CRB 1.—The striking difference between the three good clones, ICS 1, 6 and 8, and the three poor ones, ICS 3, 4 and 5, has been maintained,

Table I.—Yields and pod values

Yields calculated as "lb. dry cacao per acre". Pod values as "pods to 1 lb. dry cacao".

Experiment and year of planting.	Clone.	Yield 1940-41	Yield 1941-42	Yield 1942-43	Yield 1943-44	Aggregate yield since planting.	Pod Value 1943-44.	Parental Pod Value.
CRB 1	ICS							
1937	1	88	148	645	739	1,620	7.5	6.3
	3	21	14	36	113	184	7.5	6.1
	4	59	54	75	260	448	8.0	6.7
	5	19	10	34	85	148	6.2	6.0
	6	85	91	470	686	1,332	6.1	5.4
	8	115	170	433	796	1,514	7.3	5.5
CRB 2	ICS							
1938	1	...	75	591	326	992	7.2	6.3
	7	...	6	38	119	163	7.4	6.3
	16	...	174	413	325	912	7.4	6.0
	22	...	42	301	161	504	8.7	6.5
	45	...	177	548	306	1,031	8.0	6.0
	53	...	56	294	214	564	9.0	6.5
CRB 3	ICS							
1939	1	...	...	357	518	875	7.9	6.3
	2	...	...	152	162	314	8.0	6.7
	9	...	...	100	172	272	8.9	7.1
	12	...	...	194	173	367	8.7	7.5
	60	...	...	347	658	1,005	6.9	6.7
	98	...	...	249	515	764	11.5	8.1
CRB 4	ICS							
1940	1	...	...	...	311	311	7.8	6.3
	44	...	...	...	124	124	9.2	6.9
	55	...	...	...	80	80	12.3	6.3
	70	...	...	...	97	97	9.5	7.8
	91	...	...	...	93	93	9.8	7.6
	95	...	...	...	279	279	11.9	7.6

and is highly significant statistically. The good clones changed their order from that of last year and returned to their original order—8, 1, 6; there are, however, no significant differences among them in yield. The poor ones improved slightly, contributing 17 per cent. of the total yield against 8 per cent. last year, but they still show no real promise.

CRB 2.—The clone order is substantially the same as last year, though ICS 45 has moved down one place and ICS 53 up one place. The difference between these two clones this year is significant only at the 5 per cent. point, and consequently the clones in this set do not fall so sharply into two groups as those of CRB 1. Nevertheless, there is the same tendency to grouping. ICS 1, 16 and 45 have consistently occupied the top three places since 1941-42, and ICS 7 has been consistently poorest.

CRB 3.—Here grouping is quite marked this year, though it was not so apparent in the first year of bearing. ICS 1, 60 and 98 are better than the rest with significance at the 1 per cent. point. ICS 60 and 98 are very different cacaos and comparison of their performance should increase in interest as they age. ICS 60 is a "near Criollo" with a pod value of less than 7 to the pound, and if it maintains its present performance will be an extremely valuable clone. ICS 98 is near the other end of the quality scale, but may prove hardier in the long run.

CRB 4.—This set is still very young, and somewhat irregular in age because it was established in unfavourable seasons and needed rather heavy supplying. ICS 95 is evidently a clone of interest for its precocity, though it has a very low pod value. In the older experiments, yields at three years have given some indication of later performance; but in this case we may still hope that more clones may join the "good" group.

Propagation Methods

The results of comparisons between cuttings and buddings are still inconclusive. In CRB 1, as a whole, cuttings are superior to buddings with a high degree of statistical significance. It has been noted in a previous report that there is a slight bias in favour of the cuttings on account of age. But in three consecutive years the total yield of cuttings in this set, expressed as a percentage of the total yield of buddings, has been 136, 147 and 141. Thus there appears no tendency for the difference to decrease with age, as it should if primarily due to relatively small differences in planting date; and we may tentatively conclude that at least some of the clones in this set are really better on their own roots than on the seedling rootstocks used.

In CRB 2, on the other hand, there does appear a tendency for the superiority of cuttings over buddings to diminish with age. Here in three consecutive years the total yield of cuttings expressed as a percentage of the total yield of buddings has been 169, 143 and 119. The last figure (1943-44) is not statistically significant.

In CRB 3 cuttings are superior and the difference between all cuttings and all buddings is significant at the 5 per cent (but not at the 1 per cent) point. There is here, also, an interesting interaction between propagation methods and clones, significant at the 5 per cent. point. The high yielding clones 1, 60 and 98 are significantly better as cuttings than as buddings; but in ICS 2 buddings are superior.

In CRB 4 the buddings were planted before the cuttings, reversing the bias due to age in the earlier sets. All buddings gave 84 kilos (wet cacao) more than all cuttings, and the critical difference for P=0.01 is only 76 kilos. This set, as it ages, should be of particular interest for comparison with the others.

The only important conclusion from all these figures at the moment is, that comparison of mixed cuttings with mixed buddings cannot give much information and may be misleading. The next step is to compare the two methods, clone by clone, using trees not less than five years old.

Given good yields in 1944-45 there should be enough data for such comparisons to be made with hopes of useful conclusions.

The interest of the comparison, apart from its immediate practical value, lies in discovering the extent to which yield in cacao is influenced by root system. The parents of these clones were all on their own roots when selected as performing far above the average, and it will therefore not be surprising to find that some of them have root systems superior to that of the average unselected seedling rootstock. On the other hand the evidence so far indicates that this is not always the case, which again is not an unexpected result.

Types of material

There is no significant difference between fan and chupon material in either CRB 1 or CRB 2. The comparison was omitted in CRB 3 and CRB 4. In both cases fan trees have actually given more cacao than chupon trees, and the difference is bigger than in 1942-43; but as the variance between blocks is also somewhat higher there is no evidence of real difference between the two kinds of material. This result follows from the lay-out of the experiments, in which the chupon v. fan comparison was assigned the smallest number of degrees of freedom because it was regarded as the least important of the questions to be answered.

Acknowledgments

These experiments were throughout the year under the care of Mr. G. E. L. Spencer. Mr. W. H. C. Knowles did the harvesting and recording in the peak months of the crop and also performed the analyses of variance. The thanks of the Botany Department are due to Mr. W. T. Dale for harvesting and recording from September to February.

PHYSIOLOGICAL AND BIOCHEMICAL RESEARCHES IN CACAO IN 1943-44

BY

E. C. HUMPHRIES

THE following is a brief report on physiological and biochemical researches carried out and completed since the publication of the Eleventh Annual Report for Cacao Research (1941-43) in 1944.

(A) Cacao Physiology

The problem of elucidating the causes of cherelle wilt have been continued. These studies have been concerned with the changes in the mineral content of the fruit during development and also the seasonal fluctuations in the carbohydrates and mineral reserve of cacao trees throughout a complete season.

(1) *Changes in mineral content of developing fruits*

Fruits were divided into age groups by means of the size/age relationship previously established, and representative samples of each group were dried in the oven and ground up for analysis. The results show that there is a continuous increase of total ash in the pulp* expressed as a percentage of residual dry weight (*i.e.*, total dry weight *minus* glucose, fructose, sucrose, starch and fat) up to the time the fruit is fully grown and is commencing to ripen (143 days), after which a considerable decrease occurs. A similar relationship was found for potassium. Phosphorus, expressed as a percentage of residual dry weight, increases at an accelerated rate after 93 days until maturity. The percentage of magnesium also increases after 93 days. Calcium declines steadily after about 80 days. In the wall, the percentage of total ash shows a downward trend until ripening commences and then increases sharply. Potassium shows a downward trend throughout, except at the ripening period when there is a big increase. Phosphorus, calcium and magnesium exhibit a downward trend throughout.

In spite of the greater dry weight of wall as compared with pulp at all stages of development, the absolute content of phosphorus in the pulp is much greater than that of the wall when the fruit is mature, there being a very large increase of phosphorus in the pulp during the pre-ripening and ripening stages. There appears to be an actual loss of phosphorus from the wall during the ripening period and it is possible that phosphorus is transferred to the pulp. The absolute amounts of potassium and calcium in the wall exceed those of the pulp throughout development. The total magnesium content of the wall is greater than that of the pulp during all stages, except at maturity when it slightly exceeds the wall value.

When the relative uptake of the mineral constituents of the wall and pulp are compared by plotting the absolute amounts on a logarithmic scale, the following relationships emerge. The relative uptake of potassium by the wall is constant up to between 50 and 60 days after which a lower but constant rate of uptake is established until about 107 days. The uptake of potassium by the pulp, on the other hand, is constant between 50 and 107 days and this rate is the same as that of the first phase in the wall. The same relationship holds for the other elements studied. The rate of uptake of any element by the wall in the second phase (57 to 107 days) is in all cases significantly lower than the rate for the first phase in the wall. Potassium has the greatest rate of any of the elements in the second phase and its rate of uptake is approximately equal to the rate of dry matter increase. Embryo division

* The term "pulp" includes all tissues within the pod wall.

commences between 50 and 60 days and the change of rate of uptake in the wall at this time appears to be associated with this fact.

By assuming that calcium is not phloem-mobile and that the relative proportions of the mineral elements in the transpiration stream are tolerably constant, it is possible to obtain an idea of the comparative importance of xylem and phloem transport during the development of the cacao fruit. This may be achieved by calculating the ratios of potassium, phosphorus and magnesium to calcium at different ages. Relatively little change in the ratio of a particular element to calcium with time would indicate that the demands for this particular element are met solely by the amount carried in the transpiration stream but an increase in the ratio at any point would indicate that the minerals are moving into the fruit *via* the phloem. This assumption is supported by the fact that the ratios in the wall of the fruit as far as phosphorus and magnesium are concerned are remarkably constant throughout the period of development; in other words, phosphorus and magnesium reach the wall almost entirely *via* the xylem in sufficient quantity to satisfy the needs of these elements, and no gradient *via* the phloem is established on their account. In the pulp, however, the ratio of any element to calcium shows a sustained increase after 75 days. It is suggested therefore that, up to 50 days, both the wall and the pulp receive their mineral elements chiefly by way of the transpiration stream, and at that time very little demand for elaborated mineral substances has arisen; hence only a slight or negligible gradient for these substances has been established in the phloem. Between 50 and 60 days, the first division of the fertilised ovum takes place but, until 75 days, the demand for elaborated substances is not very great and the transport of minerals is still mainly *via* the xylem. After 75 days, the element/calcium ratio increases steadily. It has previously been pointed out that a cacao fruit is susceptible to wilt up to a period of 75 days, a time when the fruit relies mainly on the xylem for its supply of mineral elements; hence it would tend to be very sensitive to water-strain or competition for minerals, either condition being likely to cause wilting. When, however, additional sources of supply *via* the phloem are available, the second condition becomes less critical.

The cacao fruit appears to be unusual in having a comparatively long period (75 days out of a total development time of 170 days) in which it is susceptible to physiological wilt, and it is concluded that this is due to the fact that, in this early period, the fruit is largely dependent on xylem transport for its supply of mineral elements. This in turn appears to depend on the fact that embryo development begins rather late (50-60 days).

(2) *Seasonal changes in the carbohydrate reserves of the cacao tree*

This investigation of seasonal carbohydrate changes was carried out on a field of mature cacao trees at River Estate. Samples were taken at intervals of a month when two groups each consisting of ten trees were sampled. Portions of bark and wood at heights of one foot, 6 feet and 12 feet from the ground were taken from each tree. There is a marked drying out of the wood in the dry season; the decrease in water content of the bark, although significant, is not so marked. Peaks in the various carbohydrate fractions (sucrose, reducing sugars and starch) coincide with the time of a general flush over the whole field. Immediately after the flush there is a marked decline in the carbohydrate content of both wood and bark. The reserves begin to increase again about 4 weeks after the flush began, *i.e.*, when the leaves are starting to harden.

The number of pods of various sizes on the tree sampled was recorded at each visit in order to obtain an indication of the seasonal trend of the crop magnitude. It was found that the difference in crop between the two groups sampled (A and B) at each visit is inversely correlated with the difference in carbohydrate reserves of the two samples. It is concluded therefore that the two groups of trees are potentially capable of bearing equal crops as far as carbohydrates are concerned but one group of trees had a smaller crop than the other group, because of the operation of some other limiting factor.

(3) *Seasonal changes in mineral reserves of the cacao tree*

Samples for mineral analysis were taken at the same time as the carbohydrate samples. It was found that there was less seasonal fluctuation in the mineral reserves than in the case of carbohydrates. In some instances, however, maximum amounts are present both in the bark and in the wood at the time of a leaf flush, after which a decline occurs as minerals are translocated to the developing leaves and stems.

There was found to be no correlation between the crop difference of the two groups and the mineral content of the two crops, *except in the case of potassium* where a negative correlation holds. In other words, potassium appears to be the factor limiting the size of the crop in the group of trees having the smaller crop.

(B) Cacao Biochemistry

(1) *The tannins of the cacao bean and their behaviour during autolysis*

Fermentation of cacao beans is regarded as an important process in developing quality but many of the changes which the bean undergoes during the process are obscure. Some changes are due to natural enzymes of the bean while others are due to various yeasts, moulds and bacteria which thrive on the mucilaginous substances which invest the bean. In an attempt to differentiate between the changes due to enzymes present in the bean and to enzymes of micro-organisms, a series of experiments was carried out in which fresh cacao beans were finely minced and allowed to autolyse and the changes in tannin components subsequently followed at successive intervals of time.

In minced bean material allowed to autolyse in air, there is a rapid decrease in tannin falling to a constant amount after 60 minutes. It is concluded that there are at least two tannin-like components in the cacao bean, namely (*a*) a portion readily oxidised (about 4 per cent. on fresh weight) and (*b*) a portion resistant to oxidation (about 2 per cent on fresh weight). The oxidisable portion is split into approximately two equal parts by cinchonine sulphate.

When minced bean material is allowed to autolyse under water, an increase instead of a decrease in tannin occurs. A tannin-precursor is therefore present in the cacao bean. This is of possible practical importance because, unless the conditions during a commercial fermentation are mainly aerobic, an increase in tannin instead of the desirable decrease may occur.

(2) *Some problems of cacao fermentation*

Fermentation of cacao beans is recorded as an essential step in the preparation of the marketable bean. It is, however, a wasteful process, and an examination of published data was undertaken to estimate the extent of this waste.

Most investigations on fermentation have been concerned with the change in percentage composition of the bean. This mode of expression does not necessarily give any idea of the absolute changes in components *per bean* since there is a concomitant loss of dry matter. It is found that the loss of dry matter per bean is quite considerable, a loss of 1.54 g. per 100 beans per day being frequent. In 7 days (the average duration of a fermentation in Trinidad), the loss is 11.2 per cent of the original dry matter. It has been established by numerous experiments that there is a percentage increase in the fat of the bean during fermentation. On an absolute basis, however, an actual loss of fat per bean occurs, amounting to approximately 4 per cent. in 8 days. Theobromine decreases markedly during fermentation (*e.g.*, 3.0 per cent. to 2.2. per cent. of the dried bean) but, on an absolute basis, as much as 40 per cent. of the original amount is lost in 7 days.

Very little information is available regarding the tannin changes during fermentation. Proteins, other nitrogenous substances and minerals are lost during fermentation. More knowledge concerning vitamin changes during fermentation is desirable.

Mincing cacao beans brings about a rapid decrease in tannin content and it is suggested that this might form a basis for an alternative method of preparation of the bean without undue wastage, an undesirable feature of the present fermentation process.

The above summary has been compiled from the following publications :—

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THE PHOSPHORUS CYCLE IN NATURE

For his presidential address to the Geological Section of the Congress of the South Eastern Union of Scientific Societies, Dr. K. P. Oakley took as his subject "Man and the Migrations of Phosphorus". For some time after the earth's formation, the phosphorus cycle in the sea was simple, the phosphate ions being built up into the earliest forms of organic life and released again at their death, the only loss occurring through the precipitation of phosphate ions accumulated at the lower levels, with the formation of sedimentary rock phosphate beds. Following the emergence of life from the sea and the colonization of dry land, a soil-plant-animal-soil cycle arose, from which phosphorus was removed in small quantities in the formation of bone beds, fossil fish or guano deposits. With the development of agriculture in historic times, however, the phosphorus cycle has been seriously upset, for systematic cropping reduces the reserves in the soil more quickly than they can be renewed from fresh sources. In the past few centuries man has attempted to restore the phosphorus balance by the use of fertilizers, derived largely from natural deposits ; but he has also accelerated the transference of phosphorus from plant and animal life to the sea, thus speeding up its cyclical migration in a two-fold manner. Although this has been of undoubted benefit to man, it will ultimately lead to a state of bankruptcy with regard to the element. The world reserves of workable mineral phosphate are within measurable distance of exhaustion, and although new sources may be discovered, a planned economy in their utilization seems called for, as no substitute for phosphate exists and it is essential to the survival of a large human population. The address included a historical account of phosphatic fertilizers.—(*Nature*, Vol. 154, No. 3920.)

COCONUT DISEASES IN JAMAICA (II)
DISEASES AFFECTING THE LEAVES, CROWN AND STEM OF COCONUTS

BY

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CIass II.—Diseases Affecting the Emerging Leaves

The heart of the coconut and the young folded leaf tissues therein can stand a considerable amount of rough treatment without serious harm to the palm. In the course of experiments bearing on bronze leaf wilt, the hearts of a number of palms were damaged, by augers, by insertion of a long steel catheter and by scorching from chemicals wedged between the bases of the leaves in the central column. By these purely artificial means various symptoms of bitten leaf were reproduced. Other malformations of the emerging leaves were caused which closely resembled some of the symptoms to be described below under St. Mary disease and would possibly have been accentuated in a wetter area.

Although pathologists have associated various diseases of the younger leaves with specific fungi, the writer thinks that high humidity coupled with possible mechanical, insect, or storm damage, and/or weakening of the coconuts from environmental causes, may lead to a number of similar diseases of the emerging leaves, which cannot always be attributed to the action of a specific fungus in each case. Such symptoms may not be noticed by the planter until the leaves affected are in the central column, or even later, that is to say six months or even a year after the original predisposing conditions occurred.

Bitten Leaf Disease

This name (or leaf bitten disease) is applied to slightly differing malformations of the young leaves as they emerge from the heart, involving the destruction of the pinnae and part of the rachis in varying degree. Briton-Jones (7) considers the disease to be originated by Phytophthora bud rot which has damaged the cabbage without killing the bud, and holds that this explanation will cover the different types of the disease described by Ashby in Jamaica (3). Varghese (25) describes the disease in Travancore as leaf rot or bitten leaf and attributes it to a fungus which he has not named. Sundararaman and Krishnaswami, as quoted by Patel (19), describe a disease in Madras under the name of shoot rot, caused by a species of *Gloeosporium*, and occurring during the heavy monsoon rains, the symptoms of which suggest it to be a form of bitten leaf.

Ashby describes two main types of this disease, which in Jamaica is normally not serious. In the 'hard' type, which he associates with a species of yeast and states to be rather more widespread, the young leaves in the cabbage remain dwarfed and the folded leaf tissues become dark brown and hard, sometimes accompanied by a gummy ooze, a condition suggestive of a response to wounding. The writer examined in detail a case of a palm that was recovering naturally from this type of the disease. On splitting open the heart, young leaves were to be seen which had been affected in various stages of development, including (i) those more fully formed and only attacked at the base as they were emerging, (ii) those which had been reduced to stumps and (iii) still younger almost undamaged leaves that appeared to be growing away from the hard rot, which was dry and not spreading*. This recovery may have been assisted by dry weather which had prevailed during the preceding six weeks and it is possible that a recurrence of heavy rain might have favoured a renewal of the rot.

The other form of bitten leaf Ashby names 'Pineapple leaf bitten disease' and ascribes to the pineapple fungus (*Thielaviopsis* (*Ceratostomella*) *paradoxa*). He states that it is confined to the wetter areas and is similar to the 'hard' type in that the leaflets and sometimes the rachis also are damaged while in the cabbage, but that it is not accompanied by the hard dark brown gummed and shrivelled appearance of the diseased portions of the young leaves.

The writer, as mentioned before, has repeatedly reproduced symptoms entirely comparable with those of both types of bitten leaf by mechanical injury caused in experimental manipulation of the heart,† and when lesions have been caused these have been found to be infected with *T. paradoxa*, which he considers not to be a primary cause of any form of bitten leaf. He agrees with Briton-Jones that *Phytophthora palmivora* may in many cases be the original cause of the subsequent appearance of bitten leaf, but considers that the disease may also be aggravated or even initiated by beetles or other insects. During wet weather the interior of the central column and the heart tissues below are continually wetted by rain water trickling down the leaves, a condition tending to encourage primary fungal attack or secondary attack on tissues mechanically damaged or previously parasitised. Sometimes *T. paradoxa* is present in a secondary rôle, at

* The whole appearance was strongly reminiscent of that of a sugar cane shoot which has been attacked by 'pokkah boeng' and has recovered subsequently.

† In one instance the heart of a palm was treated with chemicals in June. In November one heart leaf was noted as having been killed by this treatment. In December a subsequent heart leaf showed the typical malformation of bitten leaf. By the end of March recovery was taking place and normal leaves being produced. On cutting open the heart at this stage both signs of hard brown rot were seen, as well as leaves deformed but not rotted.

others the damaged tissues react by a type of gum formation that inhibits fungi. When the final symptoms are observed however it is not always possible to determine the original cause with certainty.

In normal years the rarity of the disease results in its often being overlooked. Sometimes natural recovery takes place, sometimes the bud is affected and death results. Excision of all diseased tissues and treatment of the remainder of the heart with a fungicide is the generally accepted remedy.

St. Mary Disease, Wet Weather Disease, Leaf Disease or Leaf Stalk Rot

In the Annual report of the Department for 1932 Smith (23) refers to a leaf disease which had been on the increase for some years, finally becoming very prevalent in the parish of St. Mary. The symptoms as described by him "consisted of "the browning of the pinnae throughout a well "defined portion of each leaf—frequently in the "middle. In some instances, instead of a brown "discolouration the affected leaflets turn an "ashen grey. In both forms of the trouble, "gummosis of the petiole in the region of the "discolouration was also apparent. In spite of "careful investigation, no pathogenic organisms "were found in association with the disease . . . ." In an address to planters Smith* gave a further account of the symptoms which in addition to the above included "the dying back of the circles "of leaves round the bud. The heart leaves "came out clean, but round that they had one or "two or perhaps half a dozen of the leaves which" (in some areas) "were turning yellow and then "getting ashen grey. Many of the leaf stalks "had brown streaks in them and there were slight "splits from which gum was oozing". Elsewhere the colour of the leaves was "more dark brown or bronze". The disease caused considerable alarm at the time, but in the course of the next two years it became much less evident, and it was quite clear that the unusual outbreak in 1932 was to be correlated with the preceding abnormal wet weather.

This form of disease having attracted most attention in St. Mary, has been called 'St. Mary disease' in Jamaica, although it is by no means confined to one parish. The name is unsatisfactory, but a better one is hard to find, as the symptoms of a number of similar types of disease, obviously closely related, are not very clearly defined. The rather loose term leaf disease covers them, but could equally well be applied to any diseased condition of leaves of any age. The name wet weather disease is apt but also rather too general, and leaf stalk rot, though correct, refers to a symptom not as a rule visible to the planter.

* Coconut Disease in St. Mary. Meeting at Highgate, *Journal of the Jamaica Agricultural Society*, 36, p.448, 1932.

Ashby (4) has described a disease which he named leaf stalk rot and which he found confined to a small area in a region of high rainfall and generally only affecting trees about 5 years old. It affected one or more of the younger open leaves of the crown and the tip of the affected leaf yellowed and withered and adjoining leaves subsequently became affected. Spots were found on the stalks of affected leaves, together with long dark patches, sometimes exuding gum. *Phytophthora parasitica* was found present and the disease was attributed to this fungus. Varghese (25) describes occasional occurrences of a similar 'leaf stalk rot' in Travancore, which only affects leaves in the crown intermediate between the youngest and the oldest. The disease spreads to adjoining leaves and in lesions on the leaf stalks a fungus was found which however was not named.

Dwyer (11) has described a maturation wilt of young coconuts in New Ireland which he attributes to soil conditions, but the leaf symptoms are worth comparison with those under discussion here. "Pronounced tip withering occurred on "the centre leaves of the affected palms and "some dying back was also seen on the outer "leaves. On the back of the petioles (leaf stalks) "of the crown leaves of the palms, pale brown "streaks were seen. These sometimes showed "up near the tip of the leaf or near the base, but, "as a general rule, commenced about two thirds-"of the way up from the base. The scattered "lesions, although moist in appearance, were "quite firm, but later they tended to spread and "link up, becoming sunken below the general "level of the outer surface of the midrib. "Eventually the diseased portions split longi-"tudinally, exposing the fibres after the ground "tissues has fallen away, and the unhealthy parts "become quite dry and hard". The various colours found in association with these lesions are described in some detail. The disease was observed after a dry period subsequent to heavy rains.

In the course of tours through the island the writer has seen a number of diseases of the maturing leaves, both with symptoms similar to those described by Smith and also resembling the leaf stalk rots and maturation wilt referred to above. These symptoms are always found in areas of high rainfall or after an abnormally wet season, and are associated either with soils that are patently not well suited to coconuts or that may have been temporarily sodden during long periods of heavy rain.

The symptoms in the most conspicuous form consist of the withering of the leaves, which may be first apparent on those immediately outside the central column. Sometimes only the tip of a leaf is affected, which as it dries out, breaks and hangs down. In other instances the leaflets throughout one or two entire leaves become brown or grey, though the leaves as a whole do not collapse. Some palms that were constantly subject to this disease shed their nuts, which

showed an unhealthy appearance when cut open. The inflorescences withered and the trunks of the affected palms were found to have large decayed areas within them. The palms in fact were inherently unhealthy. Finally there are the cases where some of the pinnae in the middle of the leaf wither, eventually leaving a portion of the midrib bare. These latter symptoms are chronic on palms in certain areas of Upper St. Mary and the adjoining portions of St. Mary, St. Catherine and St. Andrew, where such coconuts as there are grow on poor soils, very deficient in phosphate and heavily eroded. The condition here seems to be more related to soil conditions than to heavy rainfall, though the area is by no means a dry one.

The varying symptoms of this disease as finally observed suggested that they originated in an earlier stage of the leaf, probably as it was emerging from the heart, and so opportunity was taken to examine the young leaves immediately after a month of fairly heavy rainfall, in a locality where the crowns of palms generally showed one or more brown leaves. It was found that on many of these young leaves, still not unfolded nor fully green, there was an appreciable amount of spotting on the terminal leaflets. In some cases this spotting was at the base of the leaflets and the decay had extended into the outer tissues of the midrib. Scale insects were observed present and other signs of insect injury were also noticed. These initial stages of the disease would not be visible from the ground, but by the time these leaves were outside the central column, the leaflets concerned would have dried out and the tip of the leaf would wither and hang down.

From spots of this nature, on young leaves, and from the dead areas found in the adjoining parts of the rachis, *Pestalozzia palmarum*, *Botryodiplodia theobromae* and *Cytospora sp.* have been obtained, but attempts to inoculate these fungi into healthy pieces of rachis maintained in the laboratory in a moist atmosphere yielded no results at the end of a period of four weeks.

When the young leaves of a coconut are being 'shot', in the interval between leaving the protection of the heart and unfolding their pinnae and turning fully green, they pass through a stage when, while still soft and very susceptible to fungus and insect injury, yet they may be exposed to both. If wet weather is prevailing and especially if this stage is prolonged owing to the palm not being in a condition of vigorous growth, it is easy to see how injury to the leaf can be initiated, which may develop to a varying extent. Furthermore, when the new leaves are being extruded, and until they have reached their full length, very rapid growth of the midrib is taking place. It is presumably when rapid growth of this nature is hampered by the environment or lack of proper nutrients, that a breakdown occurs in the newly forming tissues of the petiole, resulting in the gum-filled cavities that are found later on, and which must interfere with the conducting vessels supplying certain of the pinnae and cause these to dry up, or become a prey to weak parasites.

It seems apparent therefore that diseases of this nature are directly attributable to environmental conditions, and while in some instances strongly parasitic fungi such as *Phytophthora parasitica* become associated, in others weaker parasites are involved. St. Mary disease is not fatal, and abnormal outbreaks related to prolonged wet weather right themselves as the weather changes. Where the disease is chronic, attention to the cultivation of the palms has been found to lessen the effects considerably, and where this improvement cannot be achieved, it is inadvisable to cultivate coconuts.

In comparing St. Mary disease to bitten leaf it is apparent that while the former affects the emerging leaves as they are expanding, the latter affects the leaves at an even earlier stage, and inflicts greater damage on them. Neither however is fatal so long as the bud remains unharmed.

Class III.—Diseases of the Whole Crown and of the Older Leaves

These diseases are, with one exception, all attributable to environmental conditions or senescence. They include premature withering and spotting of the outer leaves, drought wilt, those types of yellowing which become evident to varying degree in the leaves of the crown as a result of unsuitable soil conditions, and the 'dwindling' diseases. The genetical condition known as false wilt is also included.

Leaf Spots

Leaf spots, associated with a number of fungi and often accompanied by the attacks of scale insects, appear on the leaves of coconuts which are not in perfect health. *Pestalozzia palmarum* Cooke, a world-wide concomitant of unhealthy coconuts, causes spots of typical form, which Varghese (25) calls leaf blight and which have been described by Ashby (2) and others, and are commonly to be seen in Jamaica, especially on weak palms. *Diplodia* spp. often accompany spots on coconut leaves and Ashby recorded these and also species of *Sphaerella*, *Cytospora* and *Phyllosticta* in association with various unhealthy conditions of the leaves. The writer agrees with Briton-Jones that the real cause of such spotting is to be found in the conditions which predispose the leaves to the attack of weak parasites, and that therefore the identity of the associated fungi is of little practical significance.

Die Back, Leaf Blight or Silver Tip

The leaflets of a perfectly healthy palm should be green throughout, except on the oldest leaf. In Jamaica at any rate such absolute perfection is seldom found, and generally the terminal leaflets of several of the oldest leaves have dried up to some extent at the tips and margins, a condition often preceded by leaf spotting. When this drying out becomes more accentuated it gives rise to the condition known as die back or leaf

blight, for which the name silver tip,* occasionally given by planters, is appropriate, as the withered portions of the leaflets have a distinctly silvery grey appearance. The disease is often accompanied also by a heavy infestation of scale insects.

On some coconut properties, where the soil is plainly unsuited to proper root development or where the palms may be lacking in nutrition, such a condition is chronic, and a varying number of the outer leaves always have a withered and blighted appearance. The symptoms become worse, as would be expected, in dry weather, and less evident with rain, but the palms so affected do not die. Such a chronic condition has been observed for instance on clays derived from coast limestone on the North coast, and is in lesser degree often to be seen throughout the island, where palms are growing on rocky limestone soil.

Sometimes this condition becomes accentuated, and the withering of the outer leaves persists, the leaves drying up faster than they are being replaced, so that in a few years the palm dies. Individual palms of 30 years old or more may be lost in this manner in plantations otherwise healthy, or only showing a slight amount of die back. This type of loss occurs both on soils over limestone, and also occasionally on alluvial soils with many water borne stones near the surface derived from limestone, which are common in the valleys of the island. When palms are lost in this manner on shallow rocky soils, a possible explanation suggests itself in underlying patches of rock near the surface, which prevent further extension of the root system. On the alluvial soils, however, it is often difficult to account for die back. It would seem to be closely connected with the water relationships of the palm, and a possible explanation is that in certain soil types the formation of a deep root system in a subsoil that is free draining and liable to dry out quickly causes periodic shortage of water supply to the outer leaves. In one instance where die back was noted on an alluvial silt, overlying sand, this was undoubtedly the explanation. In other cases it is also possible that soil factors inhibit the formation of water absorbing roots. It has not proved possible to reproduce die back artificially by partial damage to the roots.

A condition akin to die back is to be found in most coconut growing countries when palms are not in full vigour. In Jamaica an early account of coconut disease by Fawcett (13) in 1887 apparently referred to it, as also did Ashby's leaf die back. Dwyer's tip wither associated with soil conditions is undoubtedly the same type of disease and Varghese refers to an 'obscure' disease in Travancore which would seem to be similar.

* Not to be confused with silver leaf and silver film, two entirely different diseases described by Dwyer (10).

Drought Wilt

Drought wilt, a term used by Dwyer (10), is a suitable name to apply to a marked wilt of the palm due to lack of water. It may or may not end in the death of the palm, depending on the prolongation of the water shortage. Cases have been seen during droughts on the Liguanea plain and in the arid Yallahs River estuary, on light quickly drying soils. In a typical instance the coconuts affected were on land which had carried bananas under irrigation. Owing to Panama disease the cultivation was abandoned, and the irrigation water cut off, except in the main channels, beside which the coconuts remained healthy. Elsewhere the palms began to wither and die as the lack of water affected them. Yellowing was not a conspicuous feature and though some nuts fell a general shedding did not take place. The leaves dried up and collapsed, often remaining pendent from the crown. The leaves in the central column remained green for some months, or sometimes dried out at the tips. Eventually the palms died. These symptoms may be compared with those obtained as a result of cutting the roots of palms in an attempt to reproduce bronze leaf wilt.

On examining palms not yet dead, but in an advanced stage of wilt, the heart was found to be sound, but the midribs of the still green leaves when split open showed decayed areas within and a breakdown of the internal tissues. The more mature nuts on cutting open appeared to be drying up, the endosperm having an abnormal discoloured or patchy appearance and the mesocarp showing brown discoloured areas and being harder and drier than usual. The opened inflorescences had dried up and the young nuts were discoloured inside. A few of the terminal flowers in an unopened spadix, which was cut open were found to be discoloured.

A wilt of a similar nature has been described by Park (18) in Ceylon and has in recent years been recognised in Trinidad, in periods of drought as being distinct from 'bronze leaf wilt'.* In Jamaica early departmental records by Fawcett (15) show that an attempt at extensive coconut planting, which was made on the Palisadoes towards the end of the 19th Century, failed from the same cause. The rainfall there averages about 33 inches per annum.

Comparison may be made between the symptoms of drought wilt and the more extreme cases of die back, both of which involve the withering of the leaves and eventual death of the palm, though in general the symptoms of drought wilt are more severe and more rapidly fatal.

Dwyer's general description of the symptoms of root disease (10) is almost identical with that of drought wilt and Ashby's description of root disease (2), on heavy and unsuitable clay soils, is also similar in many respects. Both resulted in a curtailment of the water supply to the palms. Attention may also be drawn to the occurrence of internal lesions in the midribs and the withering

* Information from private communication.

of flowers of unthrifty palms affected by water shortage, which were also found in the case of palms badly affected by St. Mary disease. Similar results attend adverse environmental conditions of varying nature.

Leaf Break

Dwyer (10) refers to a number of diseases in different parts of the world in which the breaking of the leaves of coconuts takes place, often associated with species of *Botryodiplodia*—e.g., the leaf break described by Gadd (16) in Ceylon. In Jamaica such breaking of leaves is to be seen occurring in unhealthy looking palms, especially those suffering from drought wilt or forms of St. Mary disease, but no specific organism is to be associated, and the breaking seems to be due to the internal lesions in the midribs already described as accompanying these diseases.

Yellowing

The yellowing of coconut leaves may either be caused by loss of chlorophyll alone, or by other changes in the pigments of the leaf as well. In some cases lack of nitrogen may be contributory, or inability to use available nitrogen owing to lack of phosphates. Loss of chlorophyll alone results in the leaves assuming a pale yellowish tinge, and is best exemplified by the lime-induced chlorosis affecting individual plants on limestone soils. Other changes in pigmentation cause various deep shades of yellow, such as accompany bronze leaf wilt, and the yellowing of palms that occurs on certain soils in dry weather.

There are two distinct causes of yellowing of coconuts in Jamaica (in addition to bronze leaf wilt), the one being lack of drainage and the other nutritional. The latter is accentuated by drought, and both may affect the majority of leaves in the crown. Dwyer (10) refers to various forms of chlorosis in New Guinea associated with soil conditions.

(*a*) *Yellowing due to lack of drainage.*—Palms suffering from lack of drainage become yellowed, sometimes including the central column. In a typical case examined the yellow of an outer leaf was found to approximate to shade 3 (aureolin) of the horticultural colour chart, as distinct from shades 5 and 6 of bronze leaf wilt. Water-logging is common in wet weather, and is often attributable to the abandonment of drainage after bananas ceased to be cultivated. As might be expected, the degree of yellowing of the palms fluctuates with changes from wetter to drier seasons. Lack of drainage is seldom fatal by itself, and many cases can be found of palms which have grown under water-logged conditions for years, except for respites in dry weather.

(*b*) *Nutritional yellowing.*—Coconuts become yellow in varying degree on several soil types, partly as a result of lack of cultivation and especially during spells of dry weather. Three main types of yellowing may be distinguished. The first is a marked pale chlorotic condition, which affects isolated palms, and is similar to that occasionally shown by individual plants of other crops, such as bananas and citrus. This is a form of true chlorosis due to a lack of iron caused by excess of lime in the immediate neighbourhood of the affected plant. The second is a slight yellowing of the older leaves which during periods of low rainfall in dry areas like Trelawny, is often widespread. In the third type, which occurs during droughts in regions normally enjoying good rainfall, the palms assume the orange yellow shade associated with bronze leaf wilt, and the whole crown, sometimes including the central column, turns yellow. The inflorescences and nuts, however, are not affected, and with the onset of rain the palms gradually resume their normal colour. This marked 'reddening' of the palms, as it is termed locally, has been noticed on Rendzina soils* near Ocho Rios, and also occurs on yellow limestone and soils from the Trappean shale series near Green River and Cambridge in the West End, and also near Port Antonio. It is possibly associated with lack of available phosphate which may hinder the plant from the proper utilisation of nitrogen.

Finally attention may be drawn to the yellow appearance of coconuts, which is to be seen on Richmond Bed soils east of Port Maria. It is intermediate between the second and third types described above. This yellowing occurs on steep hillsides where coconuts are growing on thin, sedentary, highly eroded clay soils derived from Carbonaceous shale (Richmond Beds). The top soil soon gives way to a hard, unyielding subsoil, causing a restricted root system. As a result, the palms are in poor condition and many tend to become yellow, especially in dry weather. The worst affected die after a few years, though by burning off the outer leaves temporary improvement is obtained, presumably owing to the lessened demand for water. This unthrifty condition of palms on Richmond Bed soils is of especial interest since, as has previously been noted, the soils are exactly similar to those on which bronze leaf wilt occurs near Lucea in the West End and according to the existing theories this disease would be expected to appear near Port Maria. It is in fact entirely absent there. It may also be noted that in dry weather a similar temporary but marked yellowing of coconuts is to be seen on Richmond Bed soils south of the area affected with bronze leaf wilt near Lucea.

Pencil Point or Little Leaf

This disease is also called by Briton-Jones tapering stem wilt, but the writer considers the use of the term wilt is misleading. It occurs fairly commonly in Jamaica, sometimes being manifested by palms in an obviously unsuitable environment, and in other cases possibly being a symptom of senescence. The diameter of the coconut trunk is an index of the vigour of the

* This term is quoted from the agricultural chemist, by whom it is applied to dark, alkaline soils, derived from soft limestone or marl and usually deficient in available phosphate.

plant, and changing circumstances during the life of a particular palm are clearly reflected in variations in the diameter of different portions of the trunk. In the case of pencil point, however, the diameter at the top of the trunk dwindles steadily until it is only a few inches across, and the crown is at the same time reduced, both in the number and size of the leaves, which appear very slowly, the axillary inflorescences never developing properly in advanced cases. When this condition has been reached it is not possible to restore the palm by cultural or manurial treatment, but on the other hand palms may exist in this condition for many years without dying. 'Pencilling' palms in an obviously unsuitable environment are often chlorotic and may show other indications of ill-health, such as boring of the stem by insects, when not more than 15 years old or so. In other cases occasional tall palms, over 40 years old, appear pencilled, but their leaves, though small, have remained green, and on cutting open the heart of such a palm it has been found to be perfectly sound. The exact explanation of pencilling, and the reason why some palms should react in this manner and not others, is not yet clear, and as it is a disease of little or no economic significance in the West Indies, it has not received detailed study. In the case of the older palms described above, as already suggested, senescence may be a contributory cause.

There has been some confusion in the relevant literature between pencil point or little leaf and the malformation of the crown due to bitten leaf, with its consequent appearance of deformed and stunted leaves. The small leaves produced by pencil point are, however, normal in form and merely reduced in size. A disease described by Dwyer (10) as frond choke is compared by him to bitten leaf, but seems to vary in some respects both from bitten leaf and little leaf, but he also refers to a 'tapering stem and reduced leaf area' in New Guinea, accompanied by chlorosis, and Varghese (25) described what is apparently pencil point under a number of obscure diseases.

Pencil point is not an infectious disease, but there are some diseases recorded elsewhere involving a reduction in size of the crown, notably the wilt or root disease described by Varghese in Travancore (25), an apparently similar disease described by Vandenberg in Guam (*Review of Applied Mycology*, 8, p. 564, 1929), another recorded by Venkatarayan in Mysore (*R. A.M.* 17, p. 295, 1938), and the 'Cadang-Cadang' Disease of the Philippines (*R. A.M.*, 17, p. 108, 1938), which are more serious than pencil point and possibly caused by viruses.

False Wilt

Palms are to be seen from time to time with a large number of withered leaves hanging down beside the stem, and a number of still green leaves similarly pendent. Briton-Jones (7) has described the same condition in Trinidad, and the writer agrees with his conclusion that the cause is genetic, the petioles of some palms being inherently too weak to support the ripening bunches of fruit, with the result that they break prematurely and the leaves remain hanging and dry up without being thrown off.

Dwyer (10) describes a similar condition in New Guinea as premature leaf-fall and leaf drop, and Cook (9), Petch (20) and Varghese (25) refer to a premature fall of leaves and nuts associated with a species of *Phytophthora*.

Class IV.—Diseases of the Stem

These are of little account in Jamaica. It is to be noted that the trunks of old palms may be seriously damaged by boring insects &c. without any very noticeable effect on the crown.

Stem Bleeding

The stem bleeding disease, associated with the fungus *Thielaviopsis* (*Ceratostomella*) *paradoxa* and reported in many parts of the tropics (7) occurs in Jamaica, where it is often originated by careless wounding of the trunk with machetes. Excision of the diseased wood and treatment of the underlying tissues with a fungicide or wood preservative is the generally accepted remedy.

Ashby (1) also describes a leaf scar disease, associated with a species of *Cytosporella*, in which the leaf scars "become dark, spongy and cracked. "The decay is quite shallow but the surface scales "off and in time a depression up to 2 inches in "depth is formed. A secondary rot favoured by "water soak is liable to develop behind the bark "below affected scars and may hollow out the "stem of the tree".

Discussion

Reviewing the coconut diseases of Jamaica as a whole, it is apparent that bronze leaf wilt is potentially the most serious, although fortunately confined to a relatively small area. The remaining diseases, except those of the stem, resolve themselves into two categories, those concerning the immature parts of the palm and those with symptoms that appear in the more mature portions of the crown. Besides bronze leaf wilt only bud rot and lightning strike are immediately fatal to the palm, and these only cause serious damage as a result of meteorological conditions over which the planter can have no control. The remaining diseases, excepting false wilt, are all attributable to the influence of environment. Where they are likely to cause more than negligible damage they can either be counteracted by following the accepted principles of good agriculture, or may be avoided by suitable choice of a planting site.

It is not possible to be very precise as to the exact causes of several of these diseases, and it is apparent that environment is more important than the presence or absence of parasitic organisms. Though the genus *Phytophthora* can be definitely associated with some, most of the fungi concerned are only present as secondary invaders of tissues already weakened by other causes. It is apparent that such symptoms as internal lesions of both the trunk and midribs,

withering of the inflorescences, an unhealthy appearance of the endosperm, or a partial shedding of nuts may be found associated with palms in the unthrifty conditions related to St. Mary disease and drought wilt, but that in such cases the palms are not necessarily doomed to die, and by suitable attention, given in time, can be restored to health. Until the "cabbage" is affected, a coconut is very hard to kill.

In Jamaica no definite root diseases of the coconut palm are caused by any fungus, but a number of diseases are clearly correlated with soil conditions.

There is still much to be discovered as to the exact relationship between the various unhealthy symptoms shown by the leaves, the reduction or otherwise in the yield of nuts, and the soil conditions responsible. For instance, the deficiency of available phosphate, which is fairly common in the soils of Jamaica, is sometimes apparently correlated with a marked chlorosis of the leaves, but in other cases it may cause a reduction or even absence of nuts on palms that show no other marked signs of ill health. The effect of die back on yields is also still largely unknown. The necessity for some research into the nutritional problems of the coconuts of the island is, however, beginning to be realised and it is hoped that this and other questions relating to the cultivation of coconuts in Jamaica will receive more attention in the future than they have done in the past.

Summary

(1) An outline is given of the history of coconut cultivation in Jamaica and the general methods at present practiced, often consisting of a combination of cattle pasture and coconuts.

(2) The diseases of coconuts are divided into four classes: (I) involving the rapid death of the bud, (bronze leaf wilt, bud rot and lightning strike), (II) affecting the emerging leaves without generally killing the bud (bitten leaf and St. Mary disease), (III) affecting the appearance of the whole crown, or of the outer leaves, but not immediately fatal (leaf spots, die back, drought wilt, leaf break, yellowing, pencil point, and false wilt), (IV) affecting the stem (stem bleeding and leaf scars).

(3) Bronze leaf wilt is dealt with in detail, and reasons are given to suggest that the present theory as to the cause of this disease is untenable.

(4) The symptoms of the other diseases listed above are described and compared, with references to these and similar diseases in other parts of the world.

(5) The relationship between coconut diseases and environmental factors in Jamaica is discussed.

Key to Diseases of Coconut Palms in Jamaica
(Including alternative colloquial names used locally and elsewhere)

A.—Symptoms appear in the Heart

(1) *Bud rot* (*Phytophthora* bud rot)
Heart dries up and falls over. Rest of crown dies later. Occurs in wet weather and especially after hurricanes.

(2) *Lightning strike*
Heart killed, usually with general damage to the crown as well. Often two or more adjoining palms are affected.

(3) *Bitten leaf* (Leaf bite, leaf rot, shoot rot)
Heart leaf and other young leaves appear deformed and stunted, typically with shortened leaflets.

(4) *Bronze leaf wilt* (West End bud rot, bacterial bud rot)
Heart dries up and falls over *after* the inflorescences have withered, the young nuts have fallen and the lower leaves have yellowed.

B.—Symptoms appear in the Crown

(*a*) *Leaves turn yellow*

(4) *Bronze leaf wilt*
Lower leaves turn orange yellow *after* the inflorescences have become discoloured and the young nuts have been shed.

(5) *Waterlogging*
Leaves turn yellow. Inflorescences not affected and no general shedding of nuts. Lack of drainage always evident.

(6) *Nutritional yellowing*
Leaves turn yellow, sometimes resembling the colour of bronze leaf wilt. Degree of yellowing varies, but is usually worse after dry weather. Inflorescences not affected and no general shedding of nuts.

(*b*) *Leaves wither and dry up to varying extent*
(*aa*) *Inner leaves affected*

(7) *St. Mary disease* (Leaf stalk rot, leaf disease, wet weather disease)
Individual leaves may dry up almost entirely, or the tips alone, or the leaflets in the middle of the leaf. Chronic in some wet areas on poor soil, but usually only becomes prominent some months after unduly wet weather.

(*bb*) *Outer leaves affected*

(*I*) *Entire leaves wither*

(8) *Drought wilt* (Wilt)
Palm looks unhealthy, outer leaves dry up and tips may break and hangs, or whole leaf hangs down and then falls. Occurs during droughts in dry areas on light soils.

(9) *False wilt* (Premature leaf fall, leaf droop)
Palm looks healthy, but a number of the lower leaves are broken by the weight of the nuts and hang down beside the trunk, subsequently withering.

(II) Only tips and edges of leaves wither

(10) *Die back* (Leaf blight, silver tip, tip wither, root disease)

The leaflets of the older leaves dry up to varying extent. The condition is generally chronic and the palm does not die, but in some forms of this disease death occurs in two or three years.

(c) Spots on the leaves

(11) *Leaf spotting*

Typically large spots, grey to dark brown, appear on the leaves of unhealthy looking palms. Leaf spotting of various kinds always occurs on the outer leaves of palms affected by any of the diseases in section B, and is generally accompanied by scale insect infestation.

(d) Whole crown is reduced in size

(12) *Pencil point* (little leaf, tapering stem wilt)

Stem becomes reduced to a point at the top and leaves become much reduced in size and numbers. Palm ultimately stops bearing.

C.—Symptoms appear on the Stem

(13) *Stem bleeding*

A reddish liquid oozes from cuts and cracks in the stem.

(14) *Leaf scar disease*

Decay originates in the leaf scars, which become spongy and cracked.

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NATURE OF THE VIRUS

In a recent article under the title of "Molecules or Nature?" Dr. Kenneth M. Smith, F.R.S., whose recent book has aroused so much interest, says in regard to the nature of the virus: "It must be admitted that in the mind of the biologist the power to multiply and the phenomenon of crystallization do not fit well together. It seems therefore as if he will have to readjust his conception of life and, like Aristotle, visualize a gradual transition from the inanimate to the animate kingdom with only a doubtful and indistinct boundary between the two. A number of plant viruses have been crystallized: but there are others which are difficult to isolate, even with centrifugal technique, being present in such small amount. Some animal viruses (*e.g.* that of yellow fever) can be so modified as to give strains that can be used for vaccination purposes. One is encouraged to hope that one day a vaccine against influenza may be produced which will be definitely effective.—(*Intern. Sugar J.*, 1944, Vol. XLVI, p. 266).

PRELIMINARY INVESTIGATIONS INTO THE FUNCTION OF THE ENDOTROPHIC MYCORRHIZA OF THEOBROMA CACAO L.

BY

D. H. LAYCOCK*

Introduction and Review of Literature

The extensive literature on mycorrhiza has been reviewed by Rayner (11) and Hatch (6). Owing to the present lack of agreement as to the significance of mycorrhiza, it is clear that every specific case should be considered separately, as the importance of the fungus in the nutrition of the higher plant undoubtedly varies in different cases. This being so, it appears that the safest definition of a mycorrhizal state is one in which a specific fungus (or fungi) is found in constant association with the root system of a particular species of plant, with no apparent pathological effect on the root, or on the plant as a whole.

The mycorrhizal habit has been shown to be of world-wide distribution, involving a considerable number of the higher plants, but its intensive study has been largely confined to temperate regions. Tropical plant species reported to have mycorrhiza include citrus (16), sugar cane (4, 5), cotton (17, 8, 4), date palm (18), tea, coffee, oil palm, coconut, cacao, vine and rubber (15), banana (1), tobacco and tomato (7), pigeon-pea and groundnut (4). Pyke (10) in 1934 described the common occurrence of a mycorrhizal association in Trinidad cacao, but no attempts were made to elucidate its true significance. The present work was started in order to supply data for the understanding of the mechanism of soil-root nutrient exchange in cacao, but in the time available it was only possible to undertake a preliminary survey of the subject.

Description of the Mycorrhiza

The following description of the mycorrhiza is based on the examination of roots collected during the period March 1943 to April 1944. Wherever possible, fresh material was examined ; otherwise, material was fixed in the field, in a mixture of equal quantities of a 6 per cent. solution of potassium dichromate and a 10 per cent. solution of glacial acetic acid. Pyke (10) described mycorrhiza found in small cacao roots 2-20 mm. long and 0.2-0.4 mm. in diameter. Roots examined in this survey were mainly larger ; whole root branches, typified by those in area X Fig. 1, were chosen, having an average length of 20-30 mm. and being 0.3-1.0 mm. in diameter. Fig. 1 is a representation of a typical small piece of the fine surface mat root system of cacao, obtained by tracing directly over the roots, floated out on a porcelain slab. Infection occurred in and along the finer branches arising from the main roots AB and AC, where both external and internal mycelium was found. The thicker main branches, the bulbous root ends, and the root initials, were not found to be infected. The most interesting conception of the external phase was obtained by direct observation of entire fine root masses mounted in water. Normally the hyphae of many different species of fungi were seen, weaving over the root surfaces, but the mycorrhizal mycelium was characteristic and easily identified, passing between the root hairs and across from one rootlet to another. The hyphae were non-septate, with distinct, uneven walls and light or dark brown granular contents, and their diameter was found to vary from 5-20μ (Fig. 2). The amount of external mycelium varied from practically none to a well developed network on each root. Some external mycelium was inevitably lost during the removal of the roots from the soil.

Free-hand sections of rootlets of the type shown (Fig. 1), made in various planes and stained with cotton-blue in lactophenol, gave a full picture of the internal phase. Penetration of the root by the mycelium did not apparently occur at any specific location ; at the point of entry appressoria were occasionally formed (Fig. 2). Long "runner roots" and root tips were free from internal mycelium. The mycelium sometimes increased in diameter on becoming internal and small numbers of hyphae penetrated the cortex to a depth of from one to five cells, depending on the size of the root. Little tangential or longitudinal hyphal development occurred until radial penetration was completed, when the growth of spreading longitudinal and tangential hyphae began, these being characteristically long, branched, and of almost constant diameter. An open cylindrical network of hyphae was therefore formed inside the cortex, this network never penetrating every cell within an infected area but sometimes forming a complete cylinder around the stele into which the mycelium never entered. Septa were occasionally seen in the mycelium, which was both inter- and intra-cellular. Internally, and adjacent to the distributive network described, hyphae were sometimes transformed into much branched, coiled masses, filling the lumina of the cells (Fig. 3). The hyphal coils, full of stainable contents, passed from cell to cell through the walls. From such coiled masses, which are termed arbuscules (4), the hyphal contents were sometimes absent, having been released into the cortical cell lumen. Arbuscule formation, with release of hyphal contents, is the stage described by Pyke

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as the " phase of digestion ". It is typical of many of the Phycomycetous endotrophic mycorrhizal associations, such as those found in cotton, citrus and tobacco. Although definite in characteristics when seen, such arbuscule formation was rarely observed in this investigation. No evidence is as yet forthcoming that " digestion " of the arbuscules takes place ; the term implies a definite anti-fungal action by the host root tissues on the arbuscules, with subsequent beneficial absorption of the released fungal contents by the higher plant. This is a general but unproven conception of the significance of arbuscules in endotrophic mycorrhizal fungi. It is suggested that until " digestion " is definitely demonstrated the term " phase of arbuscule disintegration " should replace the term " phase of digestion ".

Certain forms of endotrophic Phycomycetous mycorrhiza show well-developed vesicles in the cortical cells. Many of these have been figured by Butler (4) and the writer has seen them in cotton roots (Fig. 4), but never in the roots of Trinidad cacao. Pyke (10), although he has applied the term " vesicle " to the appressoria formed immediately before and after penetration by the external hyphae, did not apparently find true vesicles. Rayner (15), referring to the various tropical crop plants possessing vesicular-arbuscular endotrophic mycorrhiza, mentions cacao, but does not give the source of the material. It is possible that the endotrophic Phycomycetous fungus found here may be actually of the type commonly associated with vesicular-arbuscular mycorrhiza, with vesicle and prolific arbuscule formation prevented by some cacao host tissue reaction, but it is not considered justifiable to use the term to describe it. In no case examined was the fungus seen to have any apparent pathological effect on the root tissue.

Many different ectotrophic mycorrhizal fungi have been obtained in pure culture by various workers but comparatively little success has been achieved by anyone working with the endotrophic type. A *Rhizoctonia* mycelium was obtained from the endophyte of Orchidaceae and *Phoma* spp. have been isolated from members of the Ericaceae, but literature records no isolation of a Phycomycetous endophyte as yet, although Margrou (9) obtained an unquestionable but limited growth from that of *Arum maculatum*, a few individual hyphae growing to a length of 6 cms. The writer's repeated attempts to isolate the cacao mycorrhizal fungus were unsuccessful. The following culture media were used :— 2 per cent. malt agar ; cacao root extract agar ; cacao bean extract agar ; synthetic soil fungi agar ; soil extract agar and a medium enriched by thiamin hydrochloride and nicotinic acid, as suggested by the work of Bonner and Erickson (3), Bonner (2), Sinclair (19), White (20) and others. The importance of essential elements and vitamins in the making of culture media is now generally realised and further work on this line may provide the key to the isolation of the cacao endophyte.

Distribution of Mycorrhiza in Trinidad Cacao

In order to obtain information on the rôle of mycorrhiza in the nutrition of the cacao tree in Trinidad, a preliminary survey was made in certain cacao growing areas covering various soil-types and involving fields of differing condition. The survey was carried out at the beginning of the wet season in 1943, when the mycorrhizal fungus was found to be present in each area. The estates sampled are listed in Table I. Mycorrhiza, similar in all respects to that of Trinidad, was found in roots of cacao from Roxborough, Lowlands, Pembroke and Woodlands Estates in Tobago, and from Yaguaraparo in Venezuela. Since no area was found to be without mycorrhiza, it was impossible to carry out comparative field observations between mycorrhizal and non-mycorrhizal areas such as has been done for certain temperate plants. It was noticed, however, that the amount of fungus present varied from one area to another and two estates, Las Hermanas (very poor cacao) and Tortuga (very good), were selected for more detailed studies.

Table I

Estate	Soil-type	State of cacao
Marper ...	Brasso Clay ...	Poor
Brigand Hill ...	Brasso Clay ...	Medium
Las Hermanas ...	Sangre Grande Silty-Clay	Poor
St. Marie ...	Sangre Grande Silty-Clay	Poor
Tortuga (Romero field)	Montserrat Silty-Clay (" Chocolate soil ")	Very good
La Vega (San Alio field)	Brasso Sand ...	Good
River (Fields 18 and 19)	Sandy Silt ; little clay	Poor
College Grounds ...	Northern Range detrital sand	Medium

In each area four plots, 100 feet square, were chosen at random away from roads and traces. When taking root samples, five trees per plot were also selected at random and all the surface roots within a 1 foot square sampling frame, at 5 feet from the trunk, were collected. A similar sample was taken on the opposite side of the tree and the two were mixed and fixed in the field. Subsequently, six fine roots were taken from each composite tree sample and examined for mycorrhiza ; thus, thirty roots were examined for each plot. Several samples were taken alternately from each area in both the wet and dry seasons.

It was found that the development of mycorrhizal mycelium was consistently greater in samples from Las Hermanas (poor cacao). Table II shows that the number of infected roots, remarkably constant in plots from the same area, was also consistently higher in Las Hermanas samples. It should be noted, however, that these findings apply only to the density of mycorrhizal infection for equal

Fig. 1. — Piece of surface root mat of cacao. Area X shows a typical root mass in which mycorrhiza occurs.

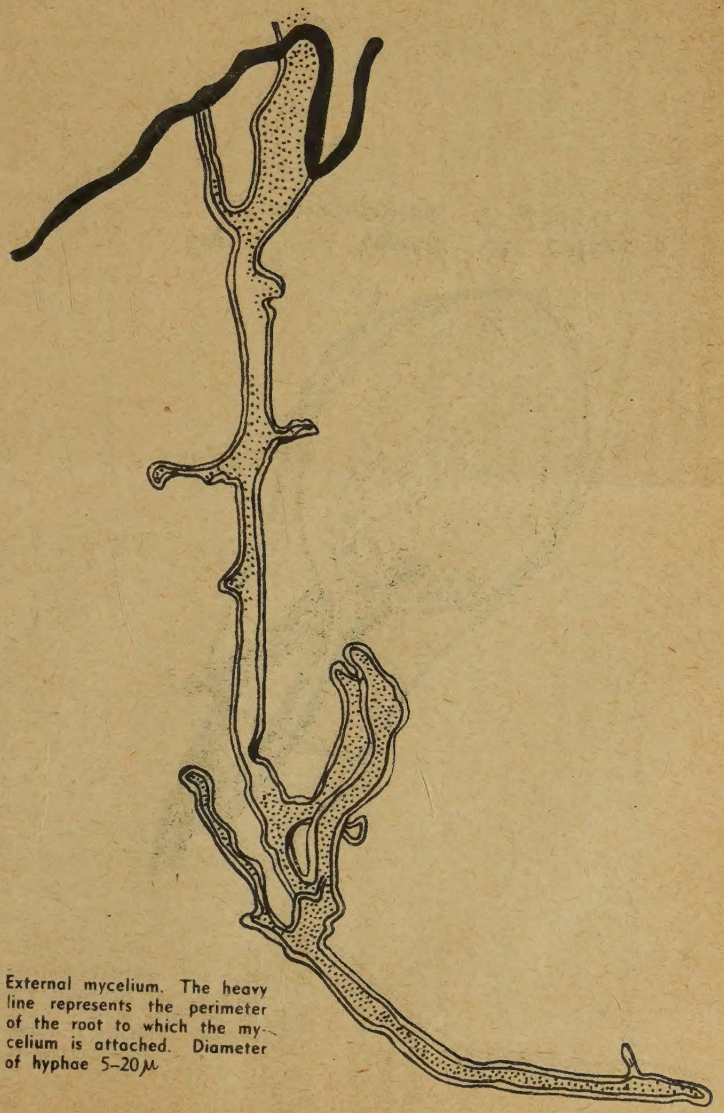

Fig. 2. — External mycelium. The heavy line represents the perimeter of the root to which the mycelium is attached. Diameter of hyphae 5–20 μ

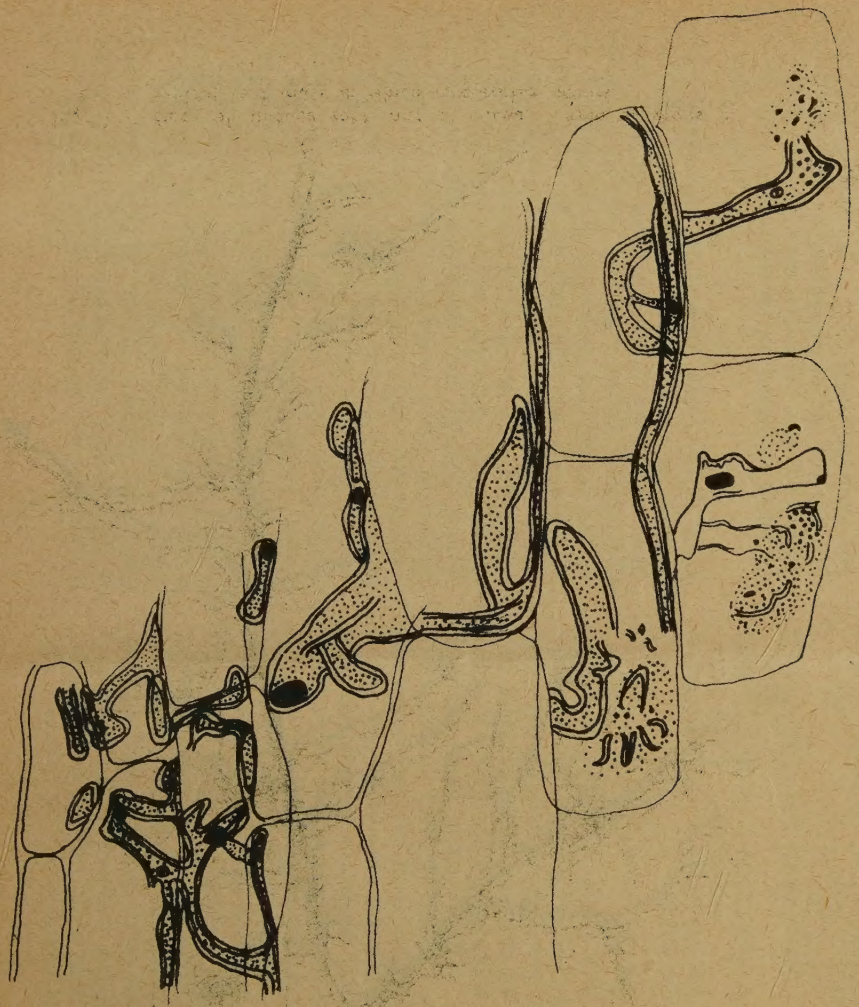

Fig. 3. — Radial longitudinal section showing internal mycelium in epidermal and cortical cells. Note longitudinal distributive hyphae and disintegrating arbuscules in the inner cortical tissues.

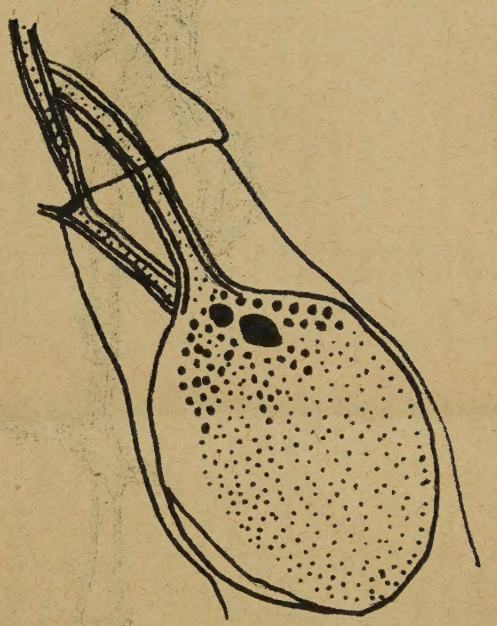

Fig. 4 — Vesicle of cotton mycorrhiza (61 x 43 μ)